

Climate Variability and Change

Natural and Human-induced



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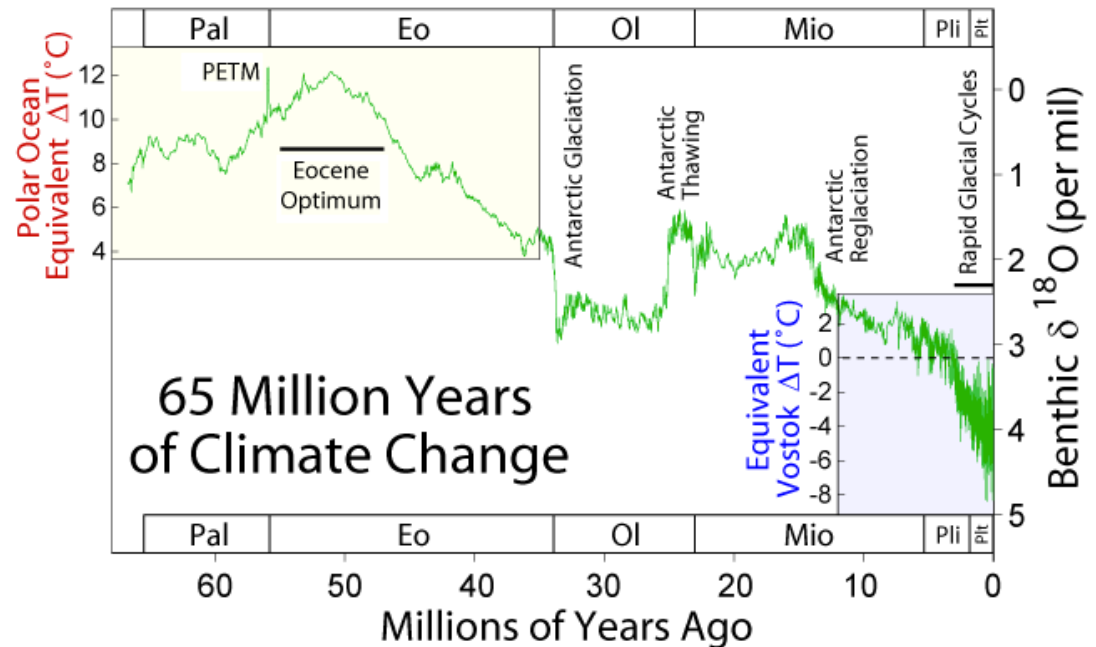
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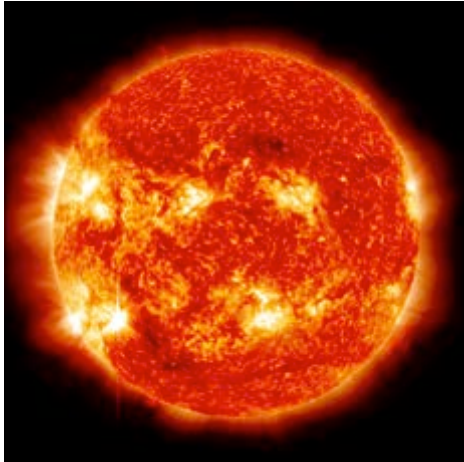
Natural Variability

Climate change is a natural phenomenon. Even if human activity were not a factor, climate would still fluctuate at various scales and timelines due to a number of factors.



What Causes Climate to Vary?

- Solar radiation
 - Sun's variability
 - Earth's orbit and tilt
- Atmospheric changes
 - Volcanic eruptions
 - Greenhouse gases
- Oceanic changes



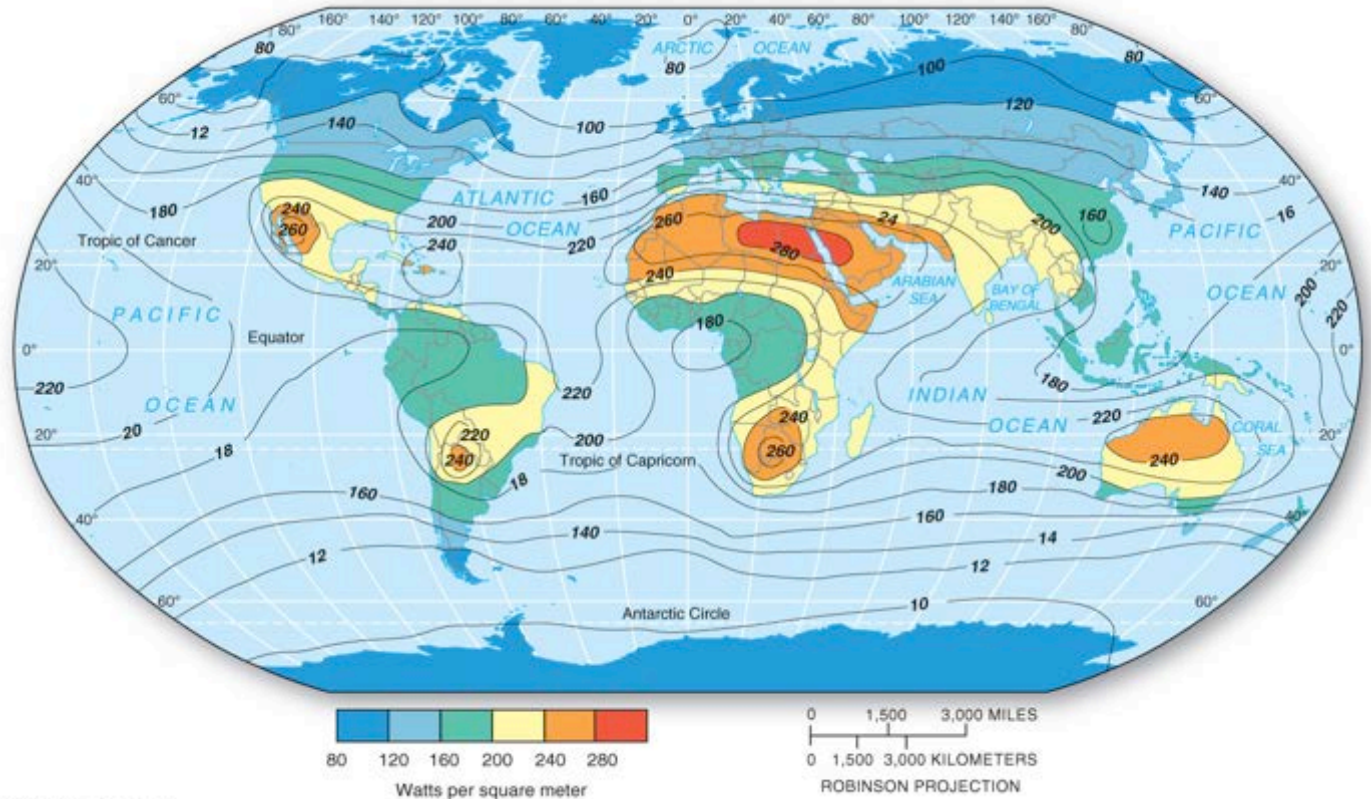
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Solar Radiation (Insolation)

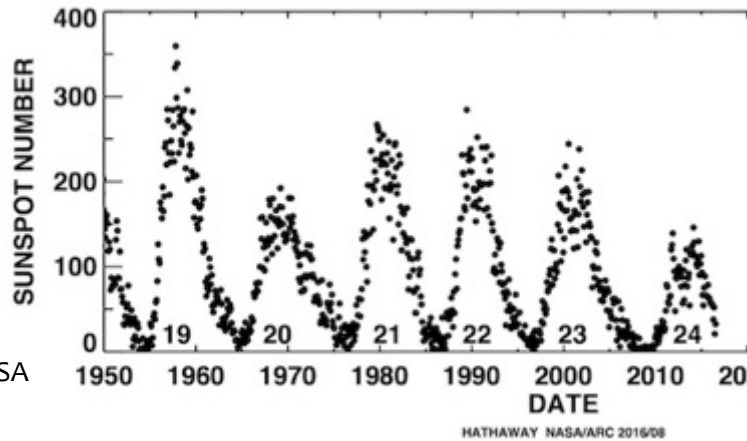
Related to orbit tilt/but also to sunspot activity, atmospheric conditions, and surface type



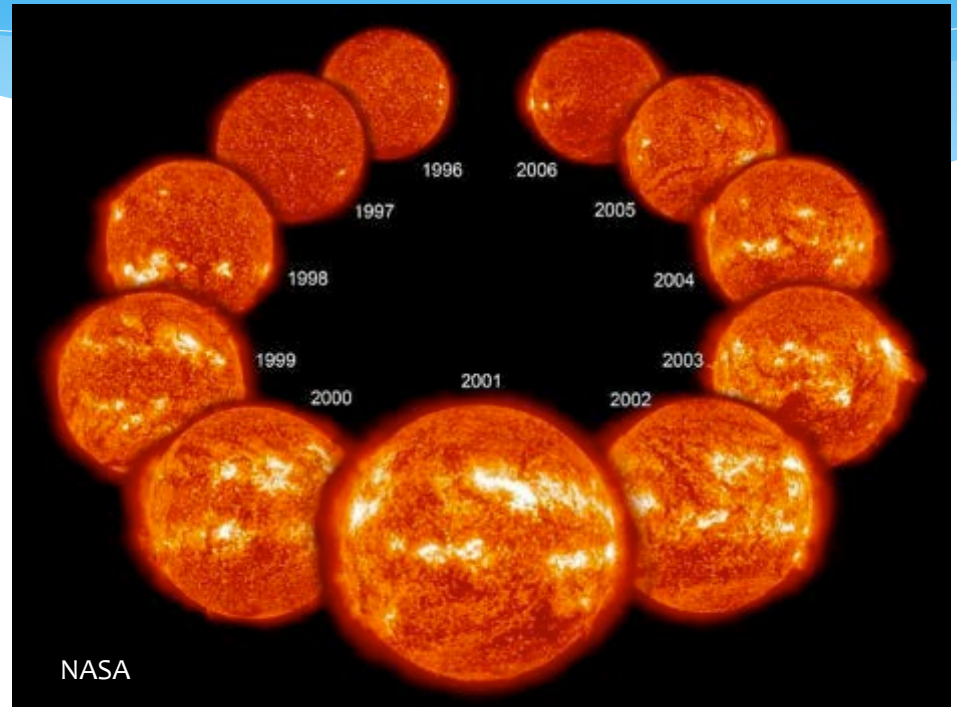
© 2012 Pearson Education, Inc.

Solar Variability

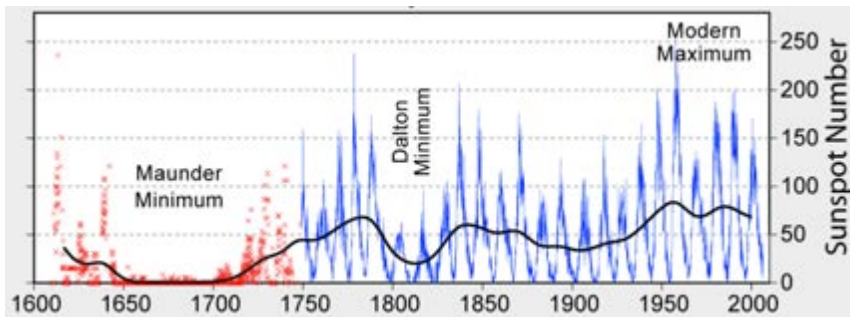
- The sun's magnetic activity varies
 - 11 year sunspot cycle



NASA

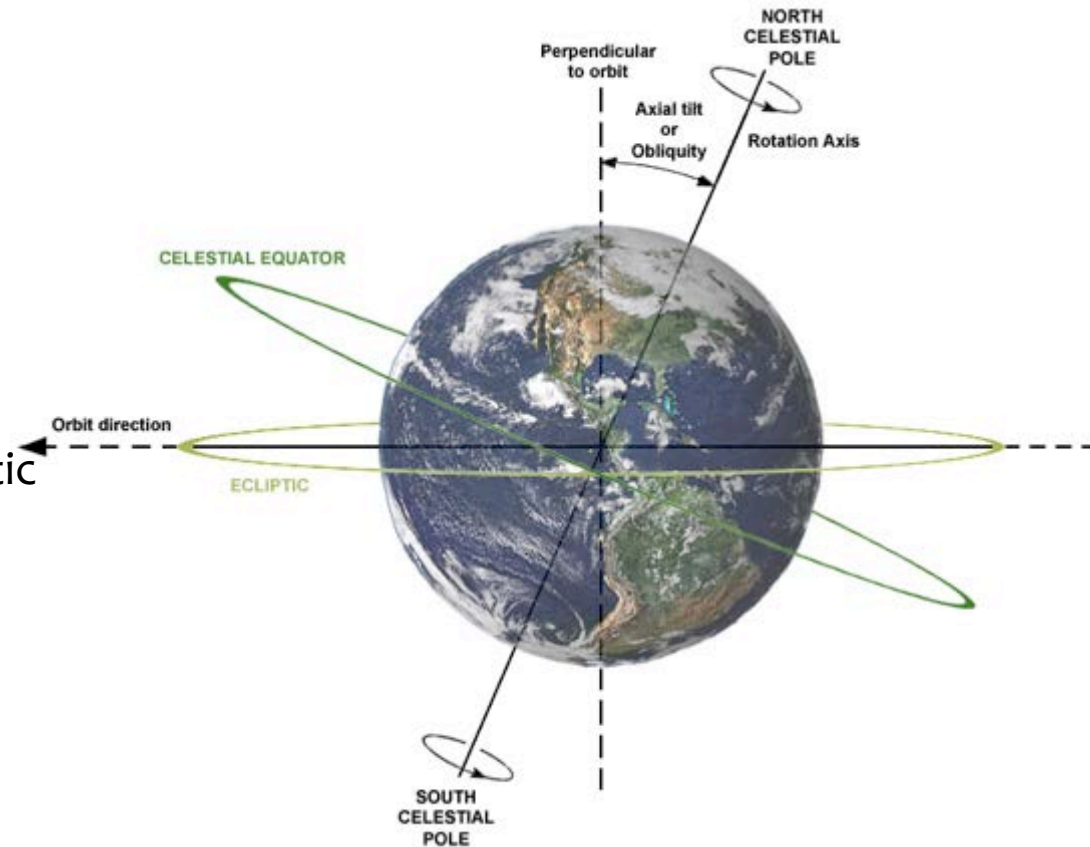


NASA



Seasons and Earth's Tilt

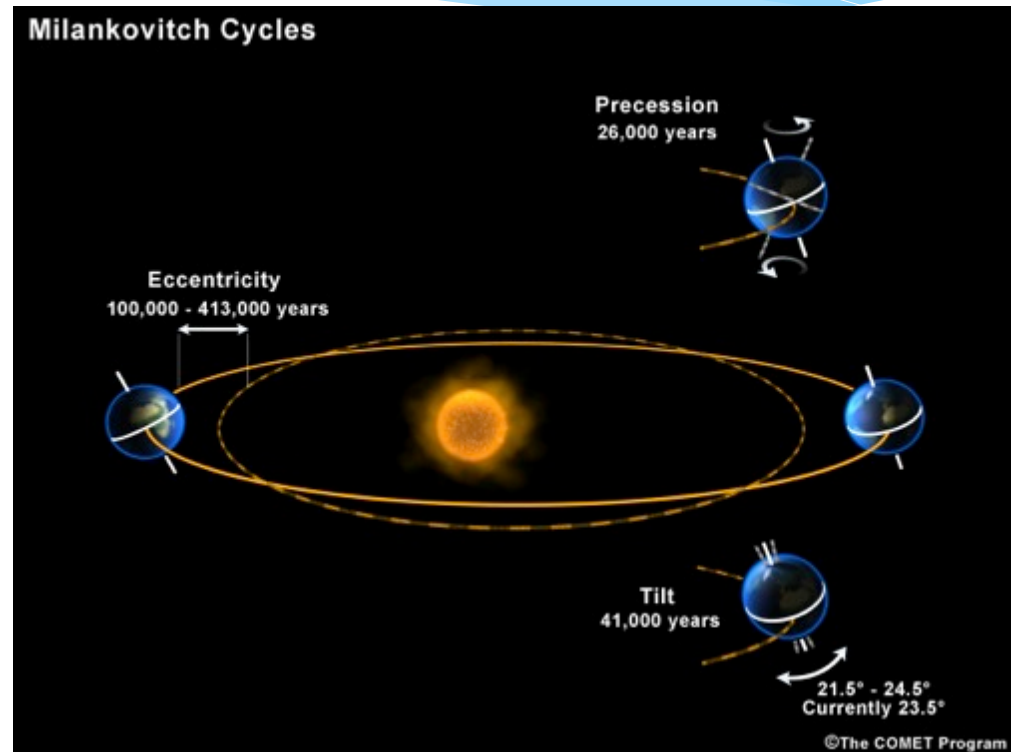
- The reason we have seasons!
- Large effect on which areas get solar radiation and what time of year
 - Tropics of Cancer and Capricorn; Arctic and Antarctic circles set by tilt, which primarily influences mid-latitude and polar regions
 - Not circular, but oval



Earth's Orbital Changes

The Earth's orbit, revolution, and tilt are not fixed on long time scales.

- Tilt shifts between 21.5- 24.5° every 41,000 years
- Eccentricity or shape of the orbit 100,000 years
- Date of Equinoxes changes, takes 21,000 years



Albedo, Sea Ice, and Snow

Positive feedback loop



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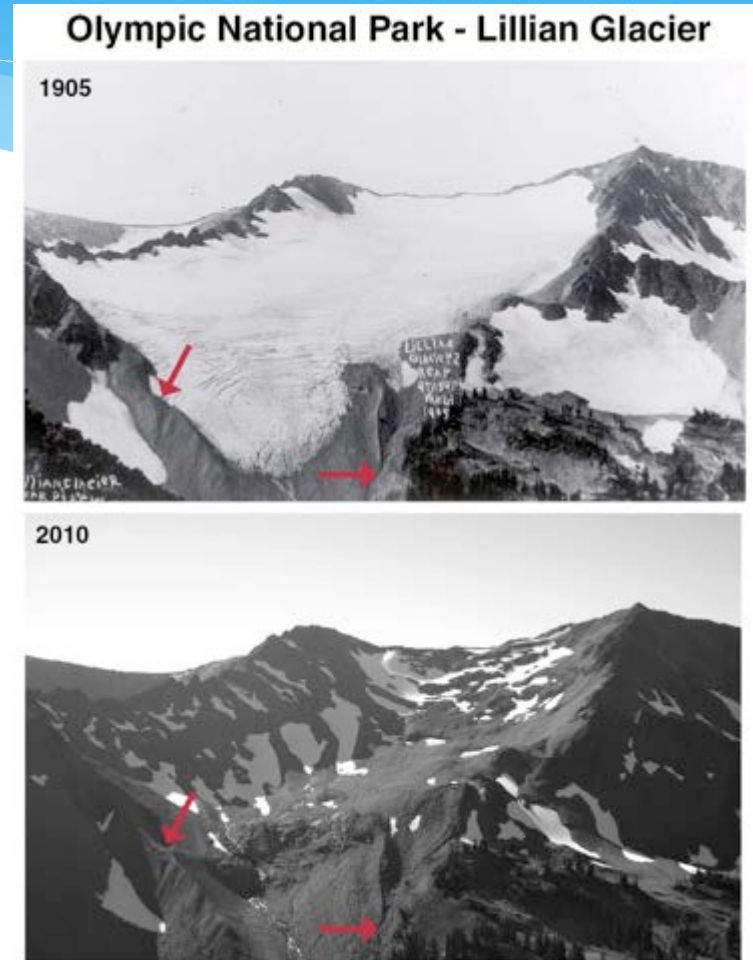
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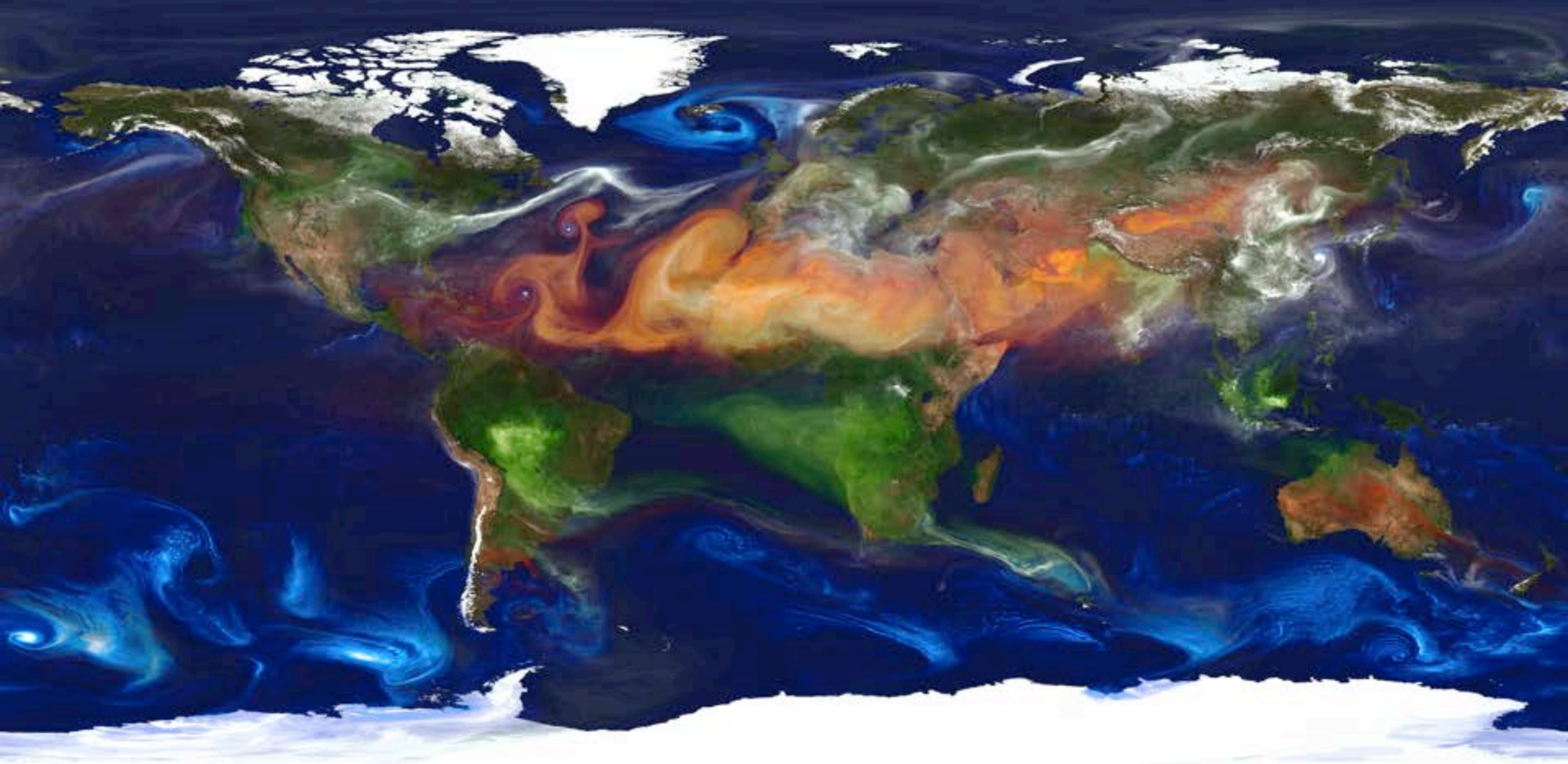


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Cascading events

- * Decrease in snow pack, leads to more energy absorbed, leading to increased temperatures.
- * Resulting in less snow pack, and higher temperatures
- * Increase in drought. Less vegetation, more fires.





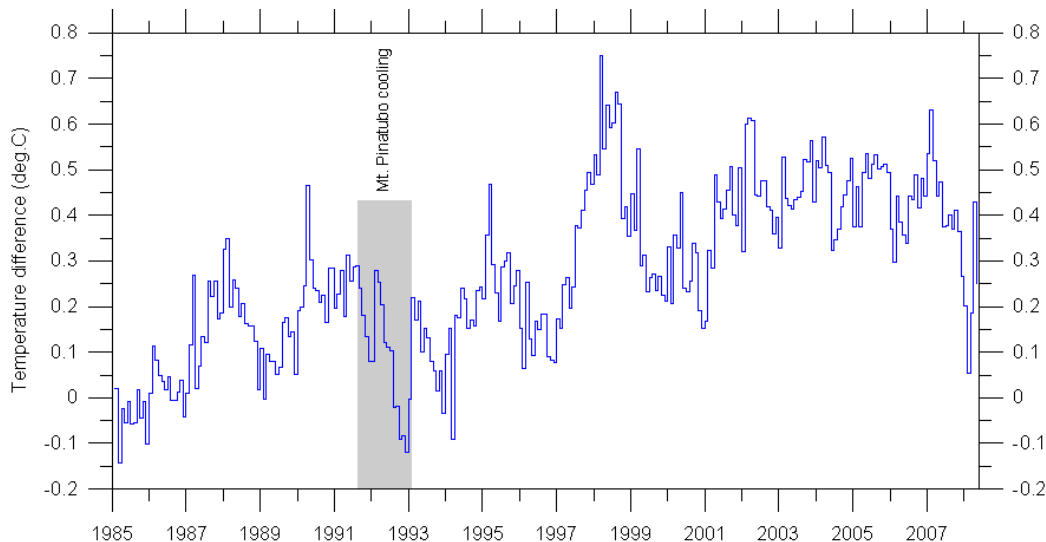
NASA

Example of different aerosols

Dust (red) is lifted from the surface, sea salt (blue) swirls inside cyclones, smoke (green) rises from fires, and sulfate particles (white) stream from volcanoes and fossil fuel emissions.

Extreme volcanic eruptions

- Longer and shorter scale
 - Longer (millions of years) – uplift and subsidence
 - Shorter (our focus) – volcanoes
 - ex: Mt Pinatubo 1991



[http://www.climate4you.com/ClimateAndVolcanoes.htm#Mount Pinatubo 1991](http://www.climate4you.com/ClimateAndVolcanoes.htm#Mount%20Pinatubo%201991)

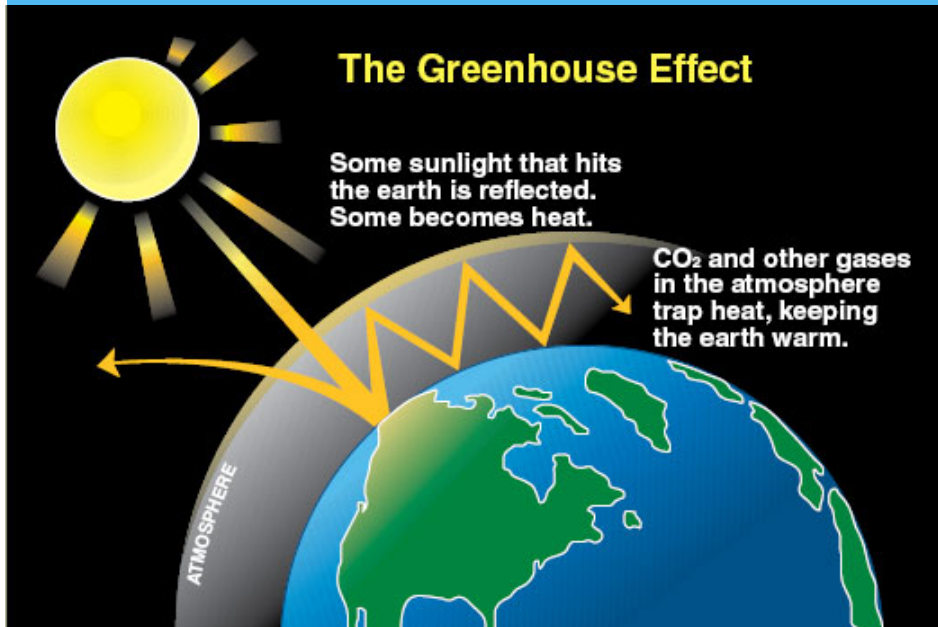


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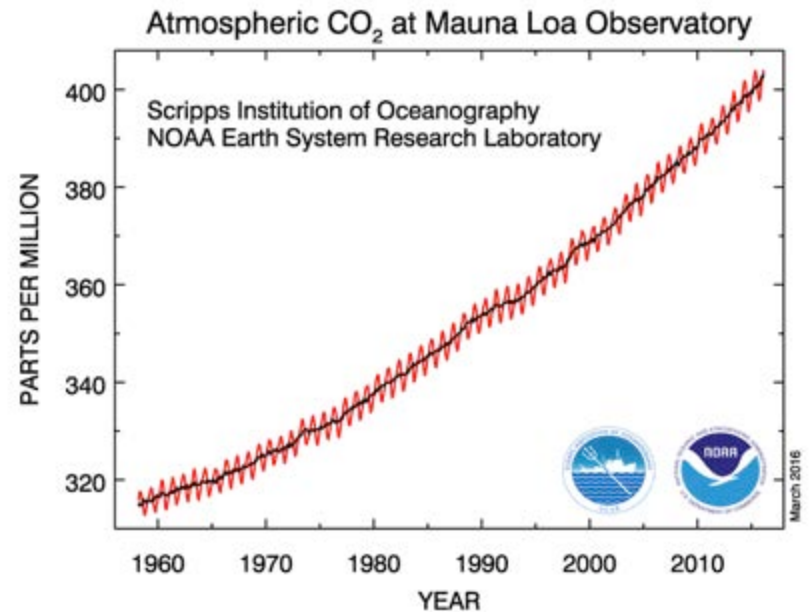
Greenhouse Gas Effect



Washington Department of Ecology

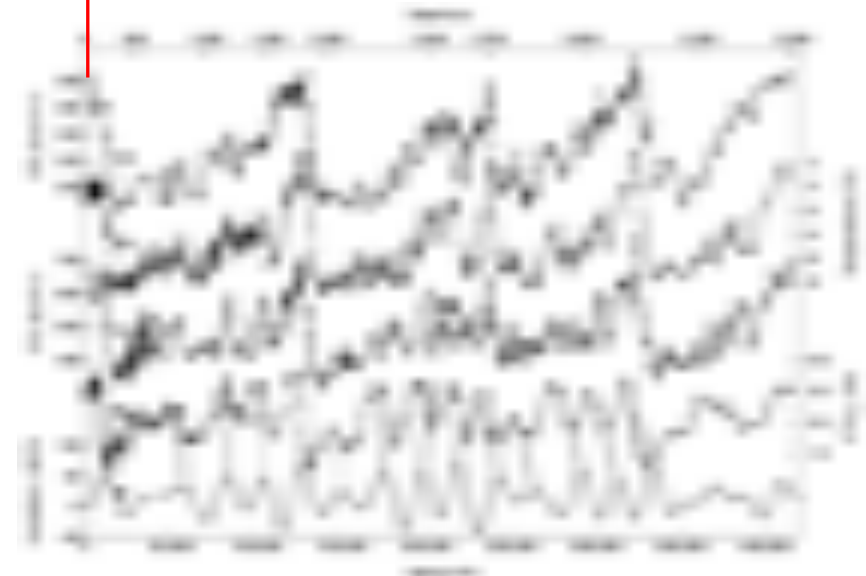
Gases (CO₂, CH₄, H₂O and others) that trap heat in atmosphere have been increasing since at least the “industrial revolution” in 19th century.

Increasing in CO₂ since the industrial revolution is linked to increasing temperature. On May 9, 2015, CO₂ passed 400 ppm for the first time since observations started.



Atmospheric Change

Today



<http://keelingcurve.ucsd.edu/>

Mauna Loa, Hawaii

11,155 feet above sea level, upper atmosphere

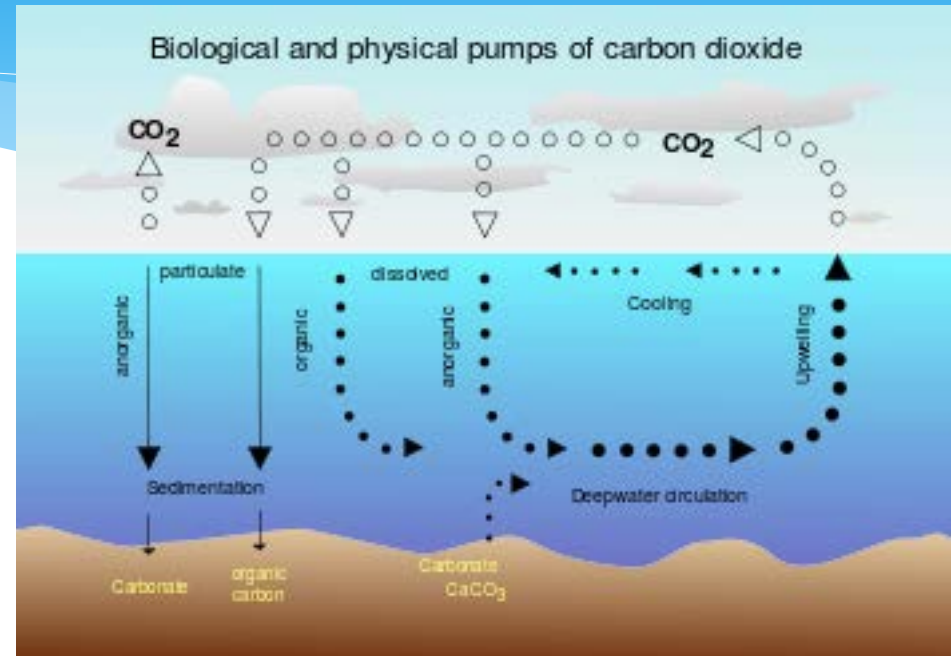
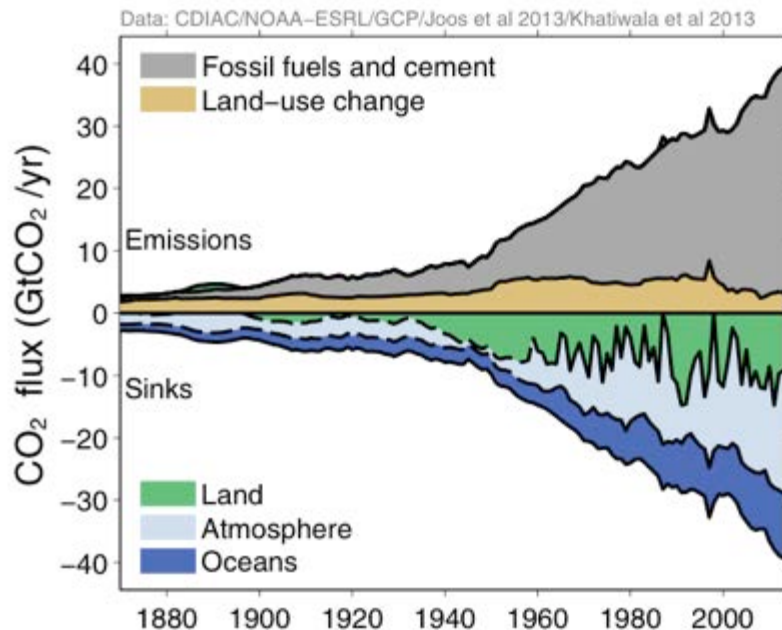


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Carbon Sinks and “Pumps”

- Primarily Forests and Deep Oceans
- Key part of natural carbon cycle
- Act to move and trap CO₂



However, human activity has been outpacing storage, or has caused dangerous changes (ocean circulation, deforestation)

Oceanic Climate Variability

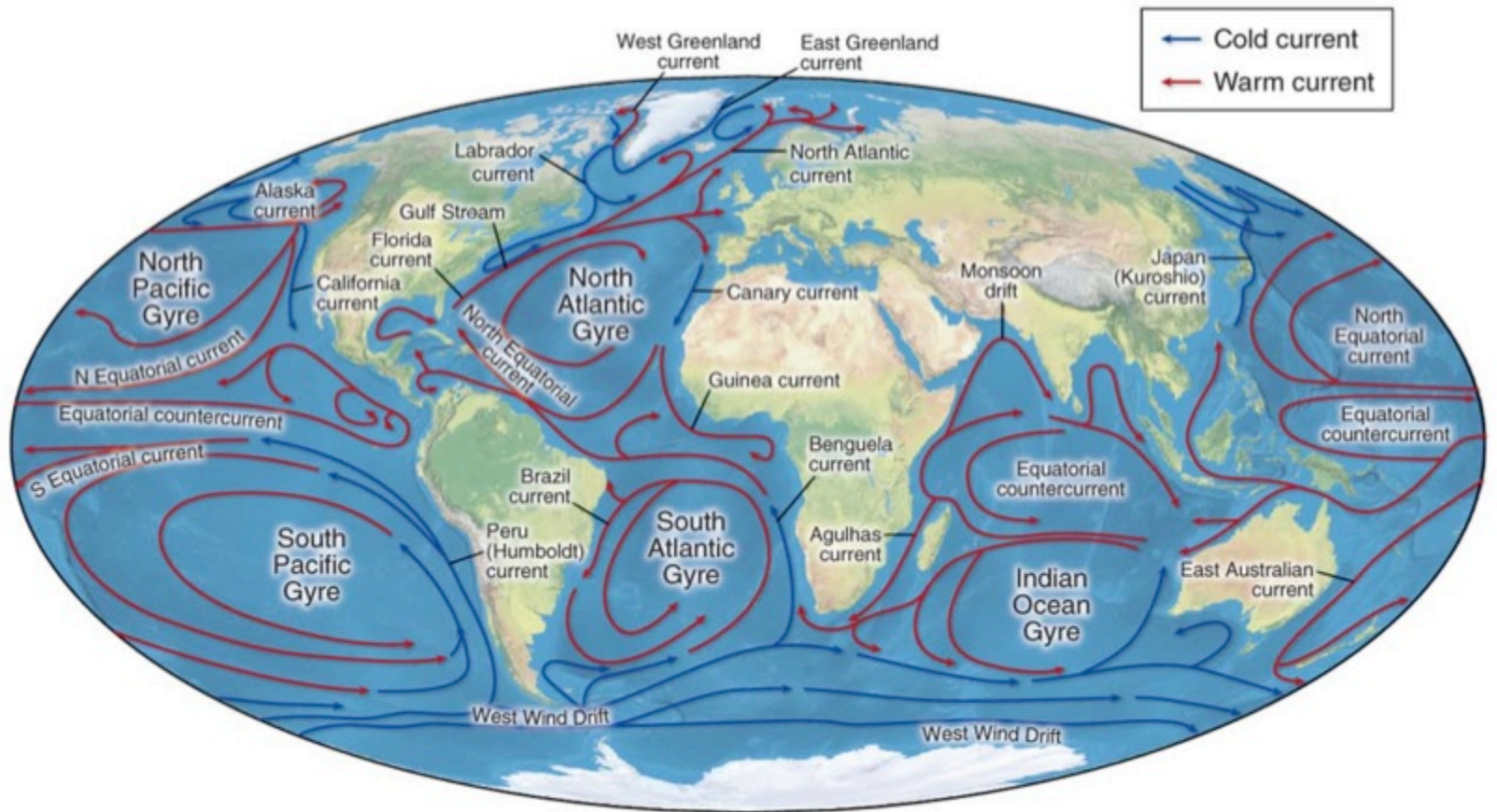


Figure 10.10
Living Physical Geography, First Edition
© 2015 W.H. Freeman and Company

Oceanic Climate Variability

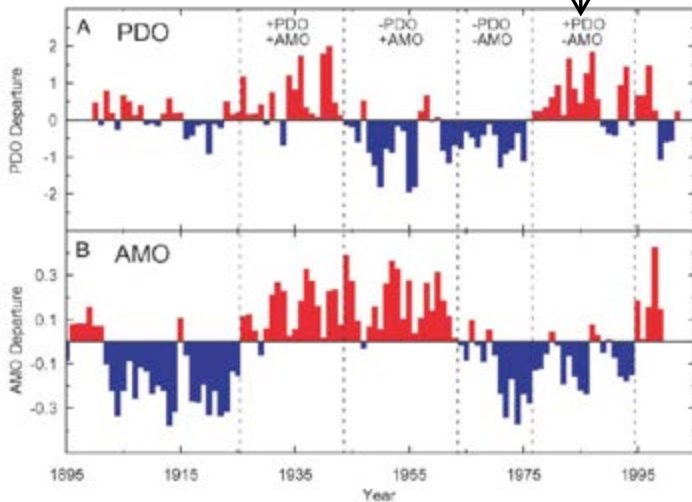
Climate “Oscillations”

ENSO – El Niño Southern Oscillation

Pacific Decadal Oscillation (PDO)

Atlantic Multidecadal Oscillation (AMO)

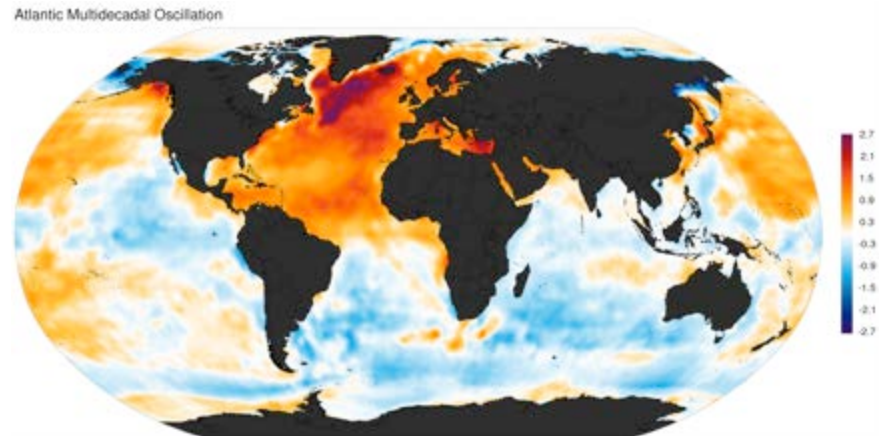
Droughts in
New Mexico



McCabe et al., 2006



PDO switches ~25 years



AMO switches ~30 years

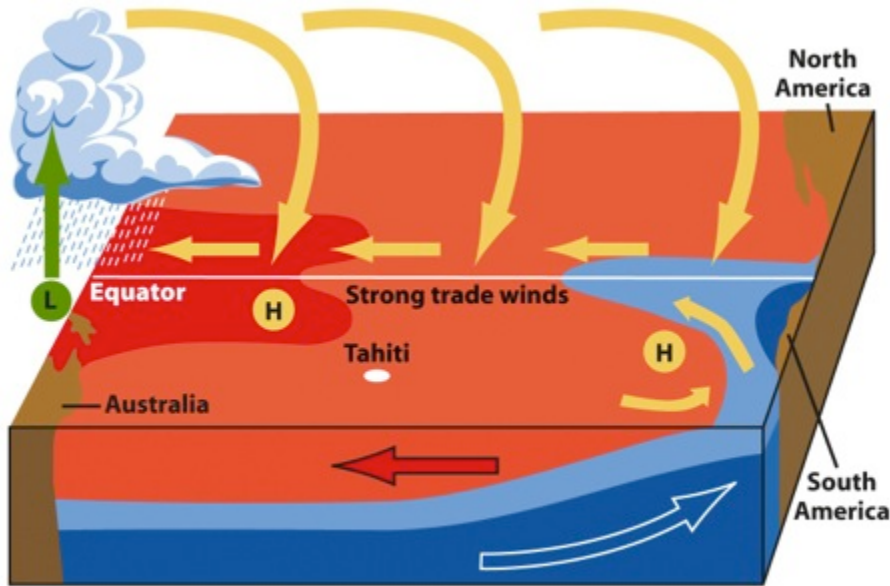


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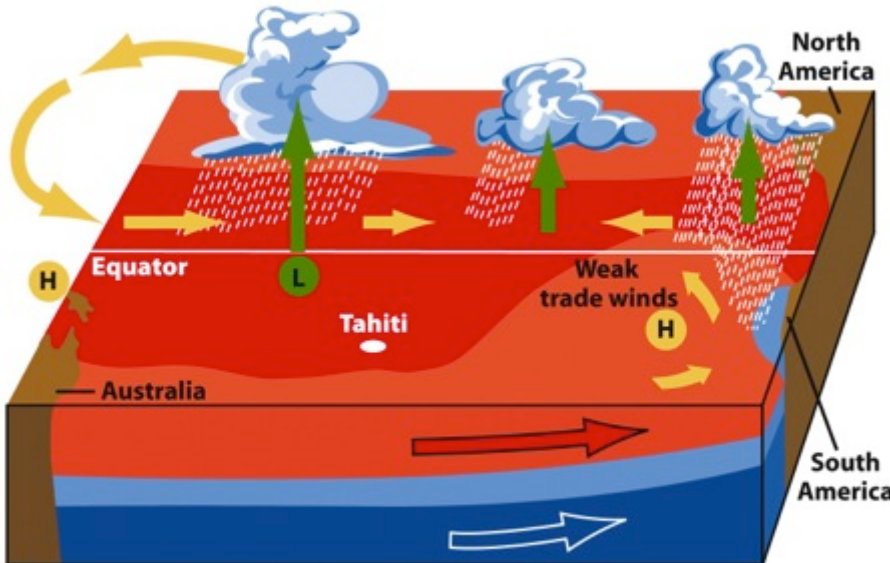
El Niño events

- 1 The trade winds weaken and S. Pacific High weakens
- 2 Sea surface temperature (SST) rises in west and into the central Pacific
- 3 SST increase in Eastern Pacific, more rain
- 4 Upwelling suppressed, less nutrients, fisheries collapse
- 5 The trans-Pacific pressure gradient is further reduced, positive feedback
- 6 Event ends when cooler water appears in central Pacific



Non El Niño year

Box 16-2a
Earth's Climate: Past and Future, Second Edition
© 2008 W.H. Freeman and Company

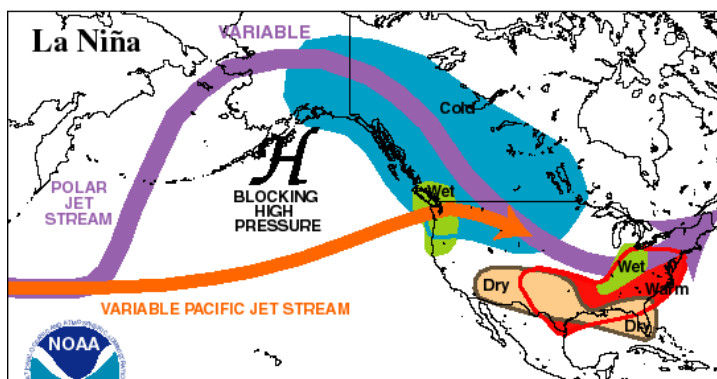
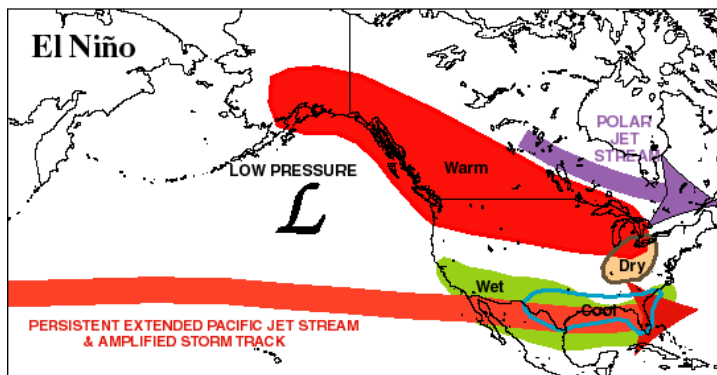


El Niño year

Box 16-2b
Earth's Climate: Past and Future, Second Edition
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ENSO

TYPICAL JANUARY-MARCH WEATHER ANOMALIES AND ATMOSPHERIC CIRCULATION DURING MODERATE TO STRONG EL NIÑO & LA NIÑA



Climate Prediction Center/NCEP/NWS

- Brings warm, wet air to SW US during El Niño events
- Brings dry air to SW US during La Niña events
- NM positively correlates with ENSO cycles year-round

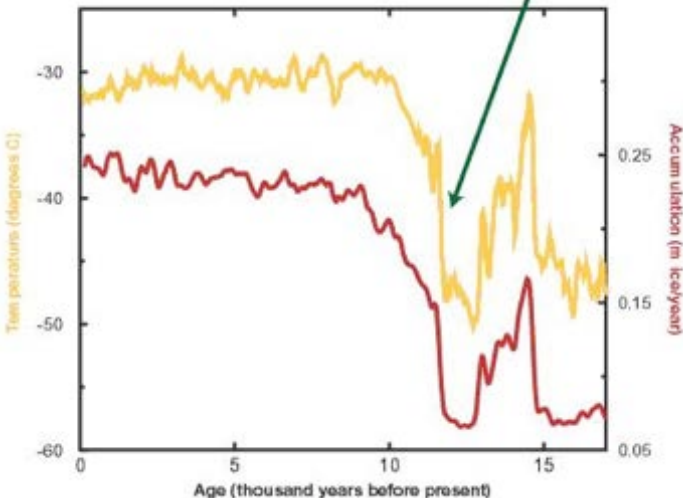


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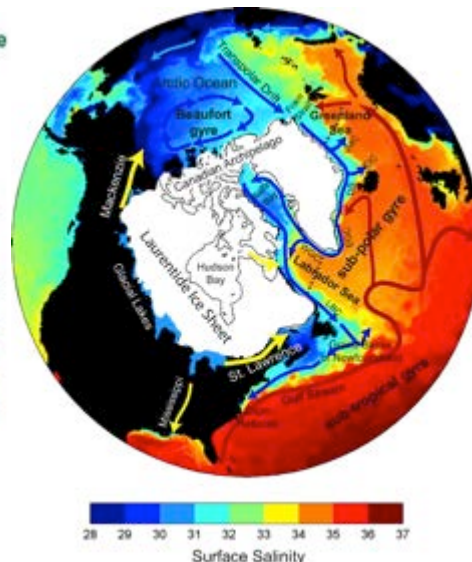


Younger Dryas

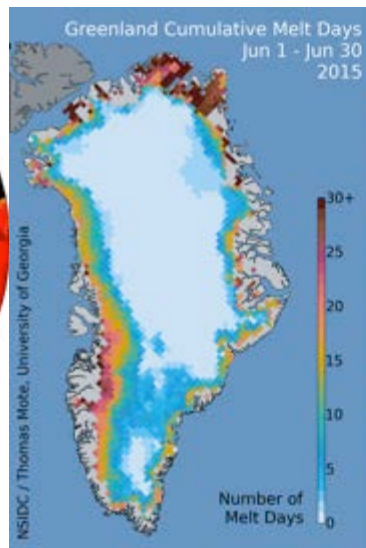
Central Greenland Climate



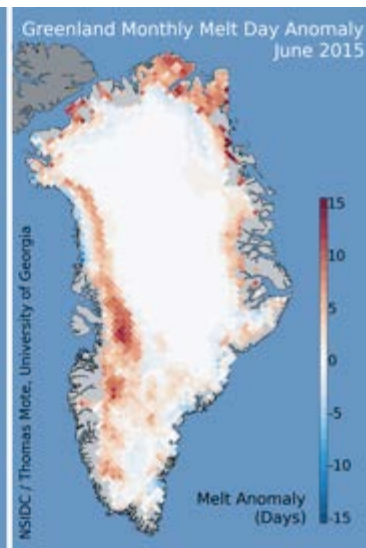
<http://www.ideo.columbia.edu>



Condon and Windsor 2012

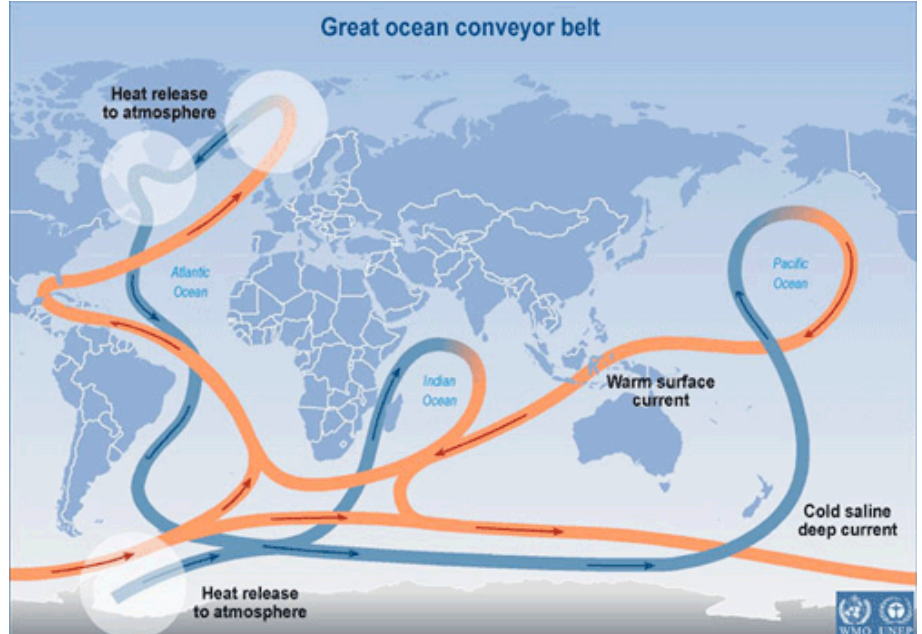


NSIDC / Thomas Moore, University of Georgia

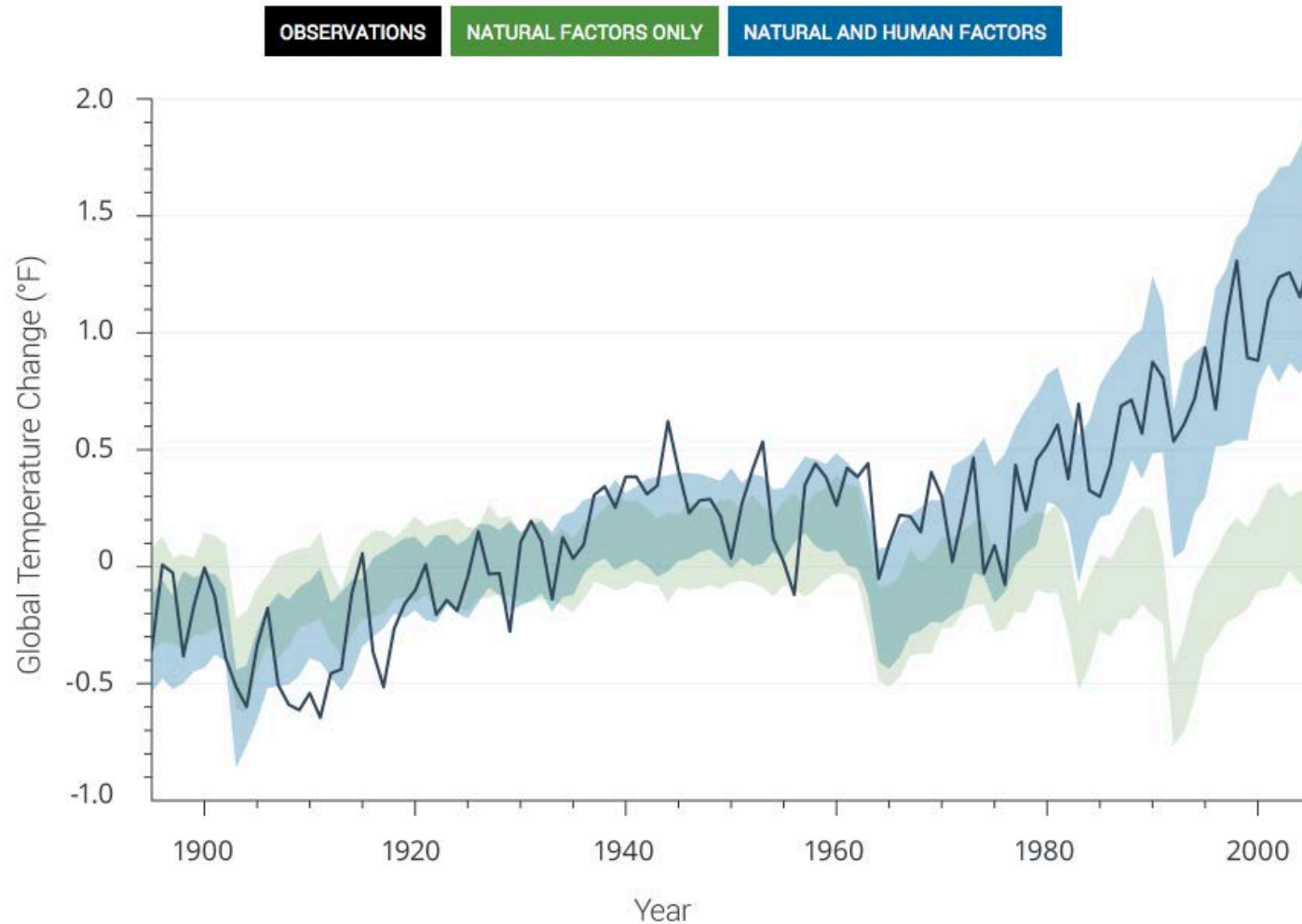


NSIDC / Thomas Moore, University of Georgia

Increased heat and/or freshwater influx can disrupt ocean circulation causing a shift in climate, that can be abrupt like the Younger Dryas, which is “natural” climate variability.

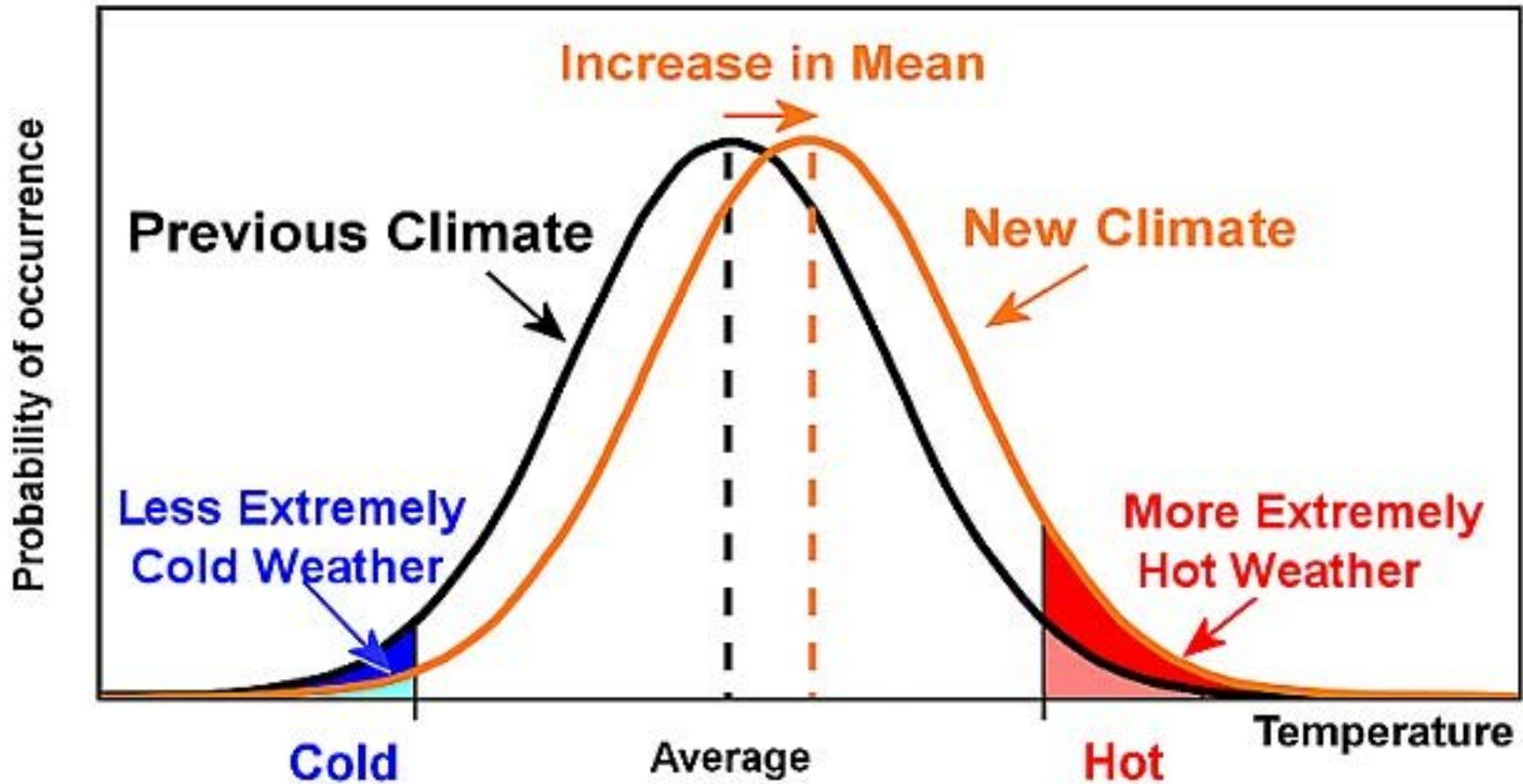


Human – Induced Change



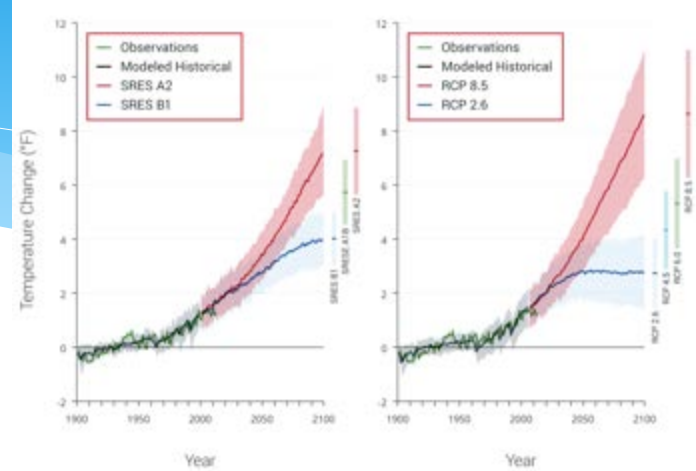
National Climate Assessment 2014

Future Climate Change

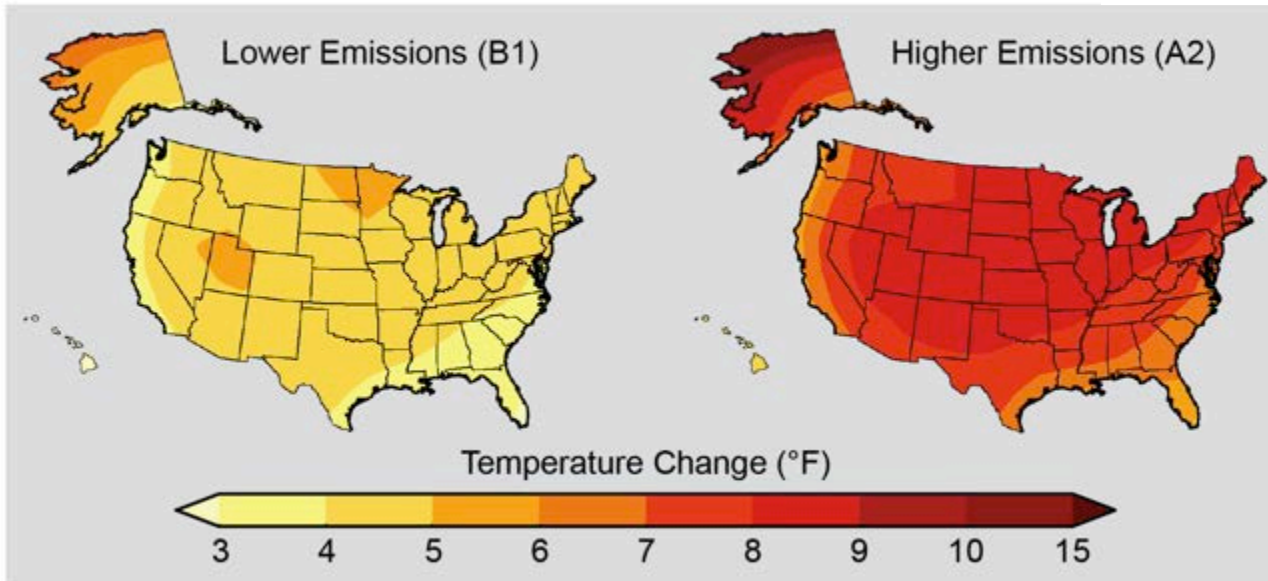


Projections

If no changes are made to reduce human impacts, we will see a major change in “normal” climate (has already started)!



Projected Temperature Change



Will cause more extreme fluctuations.